INERTIAL CONFINEMENT FUSION

Lawrence Livermore National Laboratory

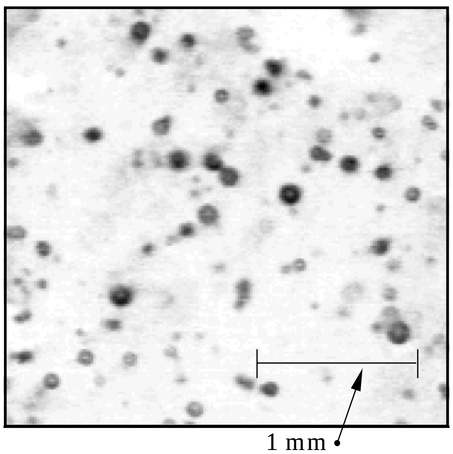
Bimonthly Update

June/July 2001

UCRL-TB-144675-01-1

Bubble Detectors Show Promise for High-Resolution Neutron Imaging on the NIF. High-resolution neutron imaging is an important Phase II diagnostic for the National Ignition Facility (NIF). Based on studies of ignition capsule failure modes using LASNEX, the current resolution specification for a neutron imaging system is 5 µm. The most critical factor in the design of a low-magnification imaging system is high spatial resolution for neutron detection. Low magnification and high-resolution detection significantly ease the requirements on aperture fabrication, characterization, alignment, and standoff from target.

Recent experiments at the University of Rochester's Laboratory for Laser Energetics (UR-LLE) OMEGA laser using customized bubble detectors based on a commercial neutron dosimeter clearly show that an image created by a penumbral aperture is properly encoded in the distribution of bubbles in the detector. The figures show an example of the bubbles created by neutron exposure and the resulting image reconstructed from the positions of several hundred bubbles created on a high-yield OMEGA shot. Detailed analysis shows that the image resolution is limited, as expected, by the detection statistics. The detection efficiency is estimated to be <1% that of a liquid bubble chamber, which is the next step in the development of an imaging system for the NIF. With liquid bubble chambers, it should be possible to achieve the 5-µm specification at neutron yields as low as 10^{15}.



Microscope photo shows small area of bubble detector. Average bubble is ~75 µm in diameter.

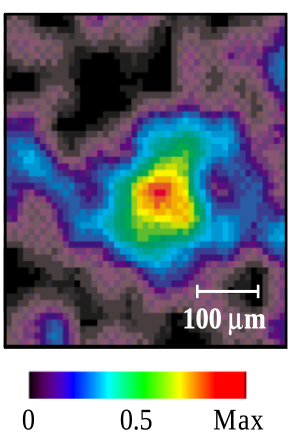
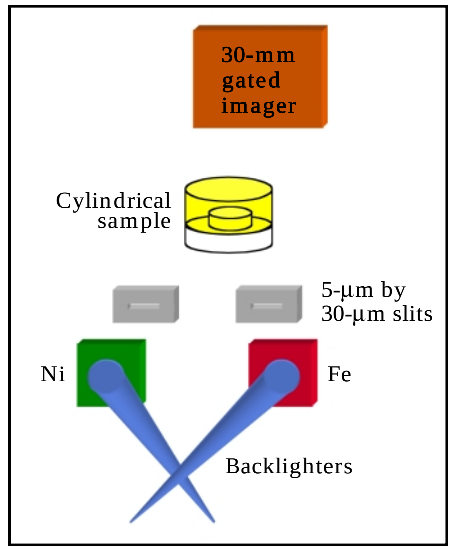
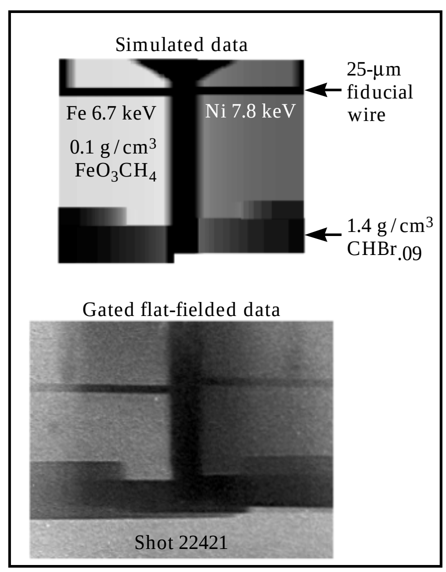


Image reconstructed from measured bubble positions.

Dual Color Radiography. Experiments at the UR-LLE OMEGA laser demonstrated a new two-color, high-spatial and high-temporal-resolution, multi-keV radiography technique. The technique allows the fraction and density of two materials to be determined, even when mixed together. Shown in the top figure is the proof-of-principle experimental setup which uses a 6.7-keV Fe He-like resonance line and 7.8-keV Ni He-like resonance line to probe with two frequencies or "colors" the same object. The colors have been chosen such that they straddle the absorption edge of one of the materials, in this case the Fe K edge in the doped foam shown in yellow. The radiography is done by projection of a line source set by backlighting two short slits. The slits allow for high resolution (4 µm measured in this case) in one direction while averaging in the orthogonal direction for improving photon collection efficiency and hence signal-to-noise. On the bottom, the predicted vs measured radiographs are compared, where lighter equates to more transmission. As expected, the Fe-doped foam transmits more of the lower energy 6.7-keV line below its K edge. By contrast, the Br-doped plastic with no absorption edges in this region transmits less of the lower energy line.





This work was performed under the auspices of the U.S. Department of Energy by University of California Lawrence Livermore National Laboratory under Contract W-7405-Eng-48.

INERTIAL CONFINEMENT FUSION
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Bimonthly Update

August/September 2001

UCRL-TB-144675-01-2

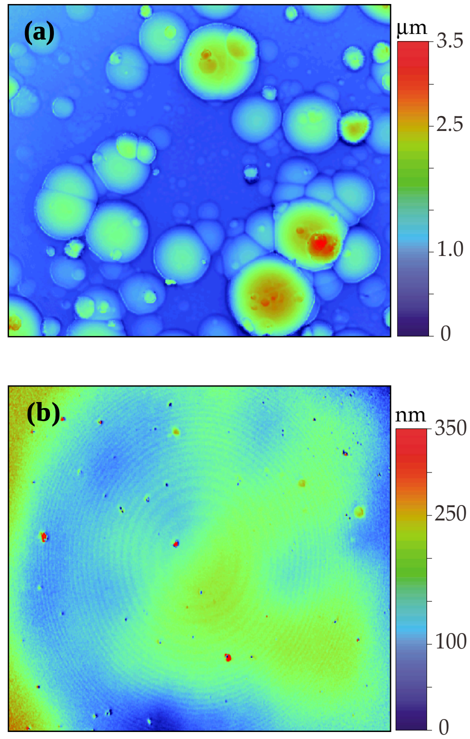

Figure 1. A 190- × 250-µm interferometric surface profile patch of a polyimide shell surface (curvature removed), before (a) and after smoothing (b). Note factor-of-10 change in color scales.

New Technique Improves Surface Finish of Polyimide Shells for NIF. The fabrication of polyimide shells for the National Ignition Facility (NIF) is a two-step process: (1) vapor deposition of polyimide precursors onto a thin spherical shell mandrel and (2) thermal curing of those precursors into the final polyimide shell. Despite improvements to the deposition process, the surface finish of the 150-µm-thick "as-coated" shell is too rough to meet specifications. We have developed a smoothing technique to reduce the surface roughness: levitating the precursor-coated shell on a flow of nitrogen gas and introducing dimethyl sulfoxide solvent vapor into the gas flow. The shell surface absorbs the vapor, leading to surface-tension–induced smoothing. After the solvent vapor exposure is complete, typically 30 minutes to several hours, we increase the temperature of the N_2 gas flow to 300°C to cure the coating and to lock in the improved surface finish. Figure 1 shows the smoothing results, in which the surface defects are decreased in height from 3 µm to less than 0.5 µm. The overall rms roughness is decreased by an order of magnitude, from 407 nm to 36 nm over modes greater than ~25. Current work focuses on improving the longer wavelength features.

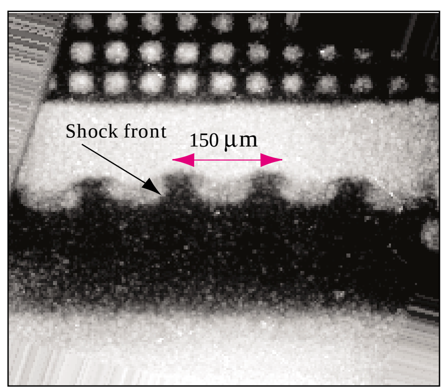

Figure 1. X-ray radiograph of interface, 10 ns after the shock has passed through the interface (21 ns after the start of the drive). The polycarbonate (dense fluid) is on the bottom.

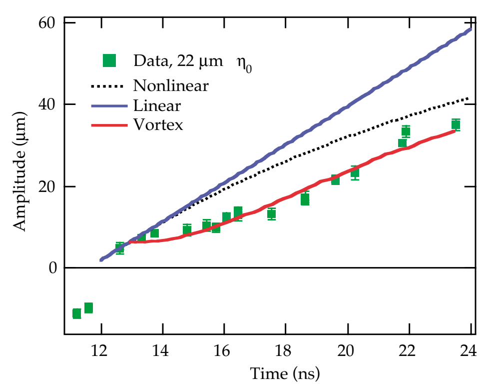

Figure 2. Amplitude (1/2 the peak-to-valley modulation) as a function of time. Linear growth (measured on small initial amplitude shots) and nonlinear saturation (after the model of Sadot) are shown as solid and dashed lines.

Experiment Shows Shock Proximity Affects Richtmyer-Meshkov Growth. In a classical shock tube experiment, a shock with a Mach number of order one passes through an interface, rapidly recedes from the interface, and does not influence the subsequent evolution of any perturbation at the interface. In a laser-driven shock tube experiment, the incident Mach number of the shock is of order ten, and the shock may continue to affect the growth of a perturbation. We have observed a reduction in the growth of a perturbation of about a factor of two compared with linear growth unaffected by shock proximity. The experiment used a laser drive at about 3×10^{13} W/cm^2, incident on a planar polycarbonate ablator (ρ = 1.2 g/cm^3). The interface was at a drop in density (to 0.1 g/cm^3 carbonized resorcinol formaldehyde foam), with an initially sinusoidal modulation of 150-µm wavelength, 22-µm initial amplitude. We diagnosed the modulation growth with time-resolved radiography (Figure 1), which showed the shock front to be significantly perturbed by the growing spikes of dense material. Figure 2 shows the resulting amplitude as a function of time. Neither analytical linear nor nonlinear growth models without shock proximity effects predict this behavior. A new vortex model has been developed to account for shock proximity.

The article entitled "Bubble Detectors Show Promise for High-Resolution Neutron Imaging on the NIF" in the June/July *ICF Bimonthly Update* describes research led by General Atomics under a DoE National Laser User Facility Grant DE-FG03-00SF22019, in collaboration with LLNL, UR-LLE, and the French CEA.

For comments about content of the *Monthly Highlights*, contact Bruce A. Hammel (925) 422-3299.
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This work was performed under the auspices of the U.S. Department of Energy by University of California Lawrence Livermore National Laboratory under Contract W-7405-Eng-48.

INERTIAL CONFINEMENT FUSION
Lawrence Livermore National Laboratory

Bimonthly Update

November/December 2001

UCRL-TB-144675-01-3

Trident Experiments Show Evidence of Ion Trapping. Recent experiments at the Trident laser facility at Los Alamos National Laboratory (LANL) applied a new, very accurate Thomson scattering technique that simultaneously characterizes the plasma conditions and the amplitudes of ion-acoustic waves in two-ion-species plasmas. The experiments, which were performed in collaboration with LANL researchers, excited and probed preformed gold / beryllium plasmas. Figure 1 shows the red- and blue-shifted ion-acoustic wave spectra with and without excitation by the stimulated Brillouin scattering (SBS) instability. A wealth of information is obtained from these data: the red-shifted peaks show the nonthermal excitation, which only affects the lighter element, while the blue-shifted peaks measure the resultant thermal changes. We observe a twofold increase of the ion temperature when exciting ion-acoustic waves to large amplitudes by SBS (Figure 2). The ion temperature increase and its correlation with SBS reflectivity measurements are the first direct quantitative evidence of hot ions created by ion trapping in laser plasmas.

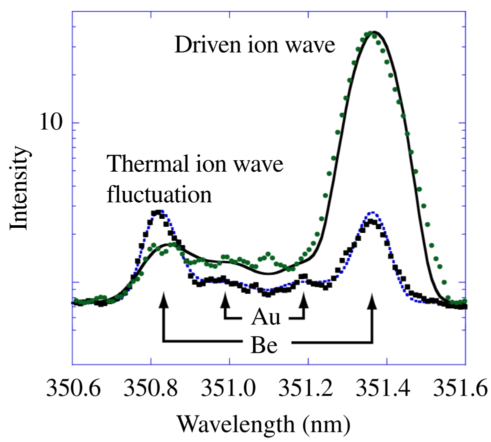

Figure1. Thomson scattering spectra show increased damping of the blue-shifted Be mode when exciting SBS with an interaction beam of 3.5×10^{15} W cm^{-2} (green circles). The data shown as black squares are taken without the interaction beam.

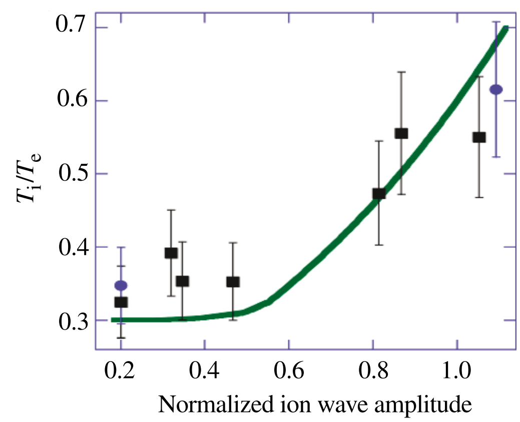

Figure 2. The ratio of ion to electron temperature shows a strong increase when exciting large ion wave amplitudes by SBS, indicating ion trapping. The solid green line is the result of modeling that infers ion trapping for the saturation of the SBS instability.

Experiments Conducted on OMEGA to Test Laser-Driven Isentropic Compression of Material. The first demonstration experiments to test a new laser-driven concept for isentropic compression of material to high pressure were conducted on the OMEGA laser at the University of Rochester's Laboratory for Laser Energetics. A low-density foam (~0.1 g / cm^3) was pressurized by a laser-driven shock wave to ~0.5 Mbar. This was allowed to unload across a vacuum gap and pressurize an Al step target (~10- to 20-µm-thick) sending an isentropic loading wave into the material. The velocity of the free surface of the steps was recorded with a line VISAR (velocity interferometer), allowing the loading histories to be determined. Several experiments were fielded with peak loading pressures in the range of ~0.2 to 0.5 Mbar. Figure 1 shows a typical VISAR record.

The shockless nature of the loading is evidenced by the smooth, continuous nature of the VISAR fringes, demonstrating that the steps accelerate without shocks. Peak velocities in excess of 10 km / s were observed in these first experiments.

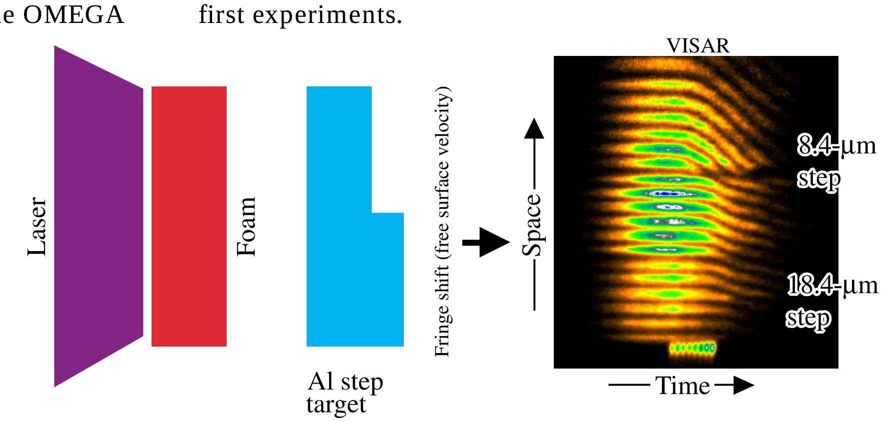

Figure 1. Experimental schematic and resulting VISAR record from an OMEGA isentropic compression experiment.

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